NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

DEVELOPMENT OF A VIRTUAL ENVIRONMENT FOR CATAPULT LAUNCH OFFICERS

by

Jeffrey Korzatkowski

March 2015

Thesis Co-Advisors: Lee Sciarini
Mathias Kolsch

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704–0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202–4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 2015	Master's Thesis 06-30-2014 to 03-20-2015

4. TITLE AND SUBTITLE

DEVELOPMENT OF A VIRTUAL ENVIRONMENT FOR CATAPULT LAUNCH OFFICERS

5. FUNDING NUMBERS

6. AUTHOR(S)

Jeffrey Korzatkowski

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this document are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol Number: N/A.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

Aircraft carriers are the centerpiece of the United States Navy. The primary weapon system of the aircraft carrier is the attached airwing and the combat power provided by its various aircraft. The airwing is only effective while airborne and thus dependent on the skill and training of a small number of launch officers known as "shooters." Shooter training is accomplished on-the-job and often requires the launch officers to go underway on different aircraft carriers, at the expense of their parent command, in order to complete their qualifications. This thesis addresses the lack of alternative environments available for shooters to hone their skills. The results of a job task analysis provide insight into the skills required to perform the duties of a launch officer. Analysis of the data gathered from the job task analysis produced a flowchart that can be represented as a finite state machine and then reproduced in a virtual environment. A virtual environment was then created utilizing current virtual reality hardware and software to faithfully re-create an environment that presented the required attributes and scenarios to accomplish the tasks of a launch officer. This thesis yields a low-cost, portable, and safe alternative environment for shooters to perform the skills required for their training.

14. SUBJECT TERMS

Virtual Reality, Catapult Launch Officer, Flight Deck, Training in Virtual Environments, Transfer of Training

15. NUMBER OF PAGES 67

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

DEVELOPMENT OF A VIRTUAL ENVIRONMENT FOR CATAPULT LAUNCH OFFICERS

Jeffrey Korzatkowski
Lieutenant Commander, United States Navy
B.S., Indiana Institute of Technology, 1997

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
March 2015

Author: Jeffrey Korzatkowski

Approved by: Lee Sciarini
Thesis Co-Advisor

Mathias Kolsch
Thesis Co-Advisor

Peter Denning
Chair, Department of Computer Science

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Aircraft carriers are the centerpiece of the United States Navy. The primary weapon system of the aircraft carrier is the attached airwing and the combat power provided by its various aircraft. The airwing is only effective while airborne and thus dependent on the skill and training of a small number of launch officers known as "shooters." Shooter training is accomplished on-the-job and often requires the launch officers to go underway on different aircraft carriers, at the expense of their parent command, in order to complete their qualifications. This thesis addresses the lack of alternative environments available for shooters to hone their skills. The results of a job task analysis provide insight into the skills required to perform the duties of a launch officer. Analysis of the data gathered from the job task analysis produced a flowchart that can be represented as a finite state machine and then reproduced in a virtual environment. A virtual environment was then created utilizing current virtual reality hardware and software to faithfully re-create an environment that presented the required attributes and scenarios to accomplish the tasks of a launch officer. This thesis yields a low-cost, portable, and safe alternative environment for shooters to perform the skills required for their training.

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

List of Figures

THIS PAGE INTENTIONALLY LEFT BLANK

List of Tables

THIS PAGE INTENTIONALLY LEFT BLANK

List of Acronyms and Abbreviations

AGO arresting gear officer

ALRE Aircraft Launch and Recovery Equipment

AR Augmented Reality

CAVE Cave Automatic Virtual Environment

CNATT Center for Naval Aviation Technical Training

COMPTUEX Composite Training Unit Exercise

CVN Nuclear Aircraft Carrier

DK Declarative Knowledge

DIF Difficulty, Importance, and Frequency

FITE Future Immersive Training Environment

FSM Finite State Machine

HMMWV High Mobility Multipurpose Wheeled Vehicle

ICCS Integrated Catapult Control Station

JBD Jet Blast Deflector

JDTA Job Duty Task Analysis

LCD Liquid Crystal Display

LOT Launch Officer Training

LSO Landing Signal Officer

MR Mixed Reality

NATOPS Naval Air Training and Operating Procedures Standardization

NPS	Naval Postgraduate School
OJT	On-the-Job Training
OLED	Organic Light-Emitting Diode
ORSE	Operational Reactor Safeguard Examination
PIA	Planned Incremental Availability
PK	Procedural Knowledge
PQS	Personnel Qualification Standard
SA	Situational Awareness
SOP	Standard Operating Procedures
VR	Virtual Reality

CHAPTER 1:
Introduction

The primary weapons system on the aircraft carrier is the carrier airwing, which consists of approximately 80 aircraft with varying capabilities. These aircraft and their highly trained crews cannot complete their missions while parked on the carrier. Aboard the aircraft carrier, the air department is responsible for ensuring that the aircraft of the airwing are fueled, positioned, launched, and recovered safely on the ship. Of the approximately 800 personnel composing the air department, only a small group of officers, roughly 10, are qualified to launch aircraft from the carrier. These officers are the catapult and arresting gear officers, known as "shooters," and, therefore, these officers are vital to the success of the airwing. Shooters complete an initial three-week training course in Lakehurst, NJ, which focuses on the catapult and arresting gear systems. After completion of this course the officers report to their ship and all training for shooter qualifications is conducted via On-the-Job Training (OJT) in accordance with a standardized Navy training and qualification manual entitled Personnel Qualification Standard (PQS). In order to complete this training and become qualified, they have to perform operations underway with aircraft. A considerable amount of time, effort, and resources are expended by the personnel within the air departments of different ships arranging to have their personnel embark on carriers to conduct training.

1.1 Problem Statement

Shooters are essential for flight operations on an aircraft carrier. Despite their critical function, there are no onboard simulation or training devices for shooters. If the aircraft carrier to which the shooter is assigned is in port, in the shipyard, or underway without the airwing embarked, there is no shooter-specific training available to them. Carriers that will be in the shipyard for a long period, such as during a Planned Incremental Availability (PIA), will send their unqualified shooters underway with another ship which is conducting training with an airwing or training command in order to get OJT and qualifications. Once qualified, shooters do not receive any proficiency or currency training. In short, launch officers would benefit from a low-cost, deployable, tool for training and proficiency.

1.2 Research Questions

1. What are the essential skills required for an officer to qualify as Arresting Gear Officer, Bow Catapult Officer, and Waist Catapult Officer?
2. Based on current training literature, which of these candidate skills can be trained effectively in a virtual environment?
3. What technical attributes does a system need to adequately represent the shooter environment for training?
4. Do current and emerging systems possess the requisite attributes for use in a shooter training environment?

1.3 Scope and Limitations

This thesis involves performing a job task analysis to determine the skills required for a launch officer to perform their duties and an assessment of which skills and tasks can be effectively performed and/or practiced in a virtual environment. Additionally, an assessment of current technologies to determine the appropriate platform for a shooter virtual environment is conducted. Finally, a virtual environment is developed for those platforms which meets the requirements identified in the first two steps. This virtual environment will not be a final training system, but rather a prototype to allow human testing which should result in a final design and implementation for fleet use.

1.4 Benefits of this Study

We hypothesize that a virtual environment for shooters can provide the following benefits:

- Increased training opportunities for unqualified shooters.
- Decreased OJT time to achieve fully-qualified status.
- Proficiency maintenance for fully-qualified shooters in the time frame between underway periods.
- The ability to conduct controlled training scenarios, including emergency procedures, in a safe environment instead of reacting to actual situations as they may (or may not) present themselves during OJT.

1.5 Thesis Organization

The remainder of this thesis is organized into six chapters.

Chapter 2 provides the background of the research. It contains a detailed description of current shooter training, training requirements, and describes the problems encountered in the current training system.

Chapter 3 provides the academic justification for this thesis: a literature review exploring the transferability of skills from the virtual to actual environments. In addition to the transfer of skills, the organization and description of job tasks are discussed. Finally, three main virtual environment technologies are examined in context of current capabilities and the questions posed by this thesis.

Chapter 4 describes the methodologies used to perform the job task analysis and creation of the virtual environment.

Chapter 5 consists of the evaluation of the job task analysis, how the results were used in the development of the virtual environment, and the results of the creation of the virtual environment.

Chapter 6 contains conclusions from this research and a discussion of future research efforts that should be conducted to extend the findings of this thesis.

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER 2:
Background

The Aircraft Launch and Recovery Officers known as "Shooters" are responsible for the safe launch and recovery of aircraft from the flight deck of a United States Nuclear Aircraft Carrier (CVN) [1]. This chapter defines the training requirements and describes the current training methods to qualify shooters.

2.1 Training Overview

According to the PQS, shooter qualification is conducted through OJT . This training method, while effective, requires the CVN and aircraft to be underway performing launch and recovery operations. While the CVN is in port or underway not performing flight operations, for example during Operational Reactor Safeguard Examination (ORSE) where the purpose of the underway is to conduct reactor drills and training, the shooters are unable to perform training or maintain proficiency in launch operations.

Other factors also impact the quality of Launch Officer Training (LOT) while underway. Training opportunities are subject to scheduling conflicts since the training requirements of shipboard personnel and aircrew are prioritized to maximize the training opportunities which will certify the battlegroup, consisting of the CVN, embarked airwing and escort ships for deployment. During the Composite Training Unit Exercise (COMPTUEX) the CVN /Airwing team are evaluated to determine if they receive their blue water certification which allows them to conduct flight operations outside the range of a land based emergency landing field. One area in which they are evaluated as part of the blue water certification process involves timing every launch and recovery cycle from the first launch to the last recovery over the span of a designated 24-hour continuous operations period. If that total time is not within the acceptable limits, the blue water certification is not awarded. Blue water certification is required prior to deployment, so during this phase of the exercise no flight deck training is conducted and only fully qualified personnel are performing flight deck operations in order to ensure that the battlegroup achieves certification. Other shipboard training conducted for pre-deployment requirements include shipboard emergency procedures, fire drills, reactor drills, deckedge training, and topside petty officer training.

Additionally, the OJT approach to LOT offers exposure to a limited subset of the scenarios that a trainee can expect to encounter while deployed. When launching aircraft from a CVN, there are numerous abnormal situations that have a high potential for catastrophic consequences if not handled correctly. Consequently, LOT in the current form is conducted when the opportunity arises and the scenarios experienced by trainees are routine in nature except under rare circumstances.

2.2 Training Requirements

In order for an officer to become fully qualified as a shooter he must complete the Aircraft Launch and Recovery Equipment Officer course at Center for Naval Aviation Technical Training (CNATT) detachment Lakehurst, NJ. Upon completion of this training course, the officer then reports to their aircraft carrier to begin the launch and recovery officer PQS. The PQS is used to record the completion of training on four watchstations: arresting gear officer (AGO), no-load operations officer, bow launch officer, and waist launch officer [2]. The commanding officer's representative, usually the air boss, signs the PQS granting qualification in each of these areas upon completion of the appropriate section of the PQS. The following are the estimated completion times for the various qualifications:

- AGO : Four weeks of flight operations
- no-load operations officer : two weeks
- bow launch officer : six weeks of flight operations
- waist launch officer : six weeks of flight operations [2]

Training for each of these watchstations must be conducted during flight operations. As previously discussed, this limitation means that training cannot be conducted while the CVN is in port or while underway performing non-flight operations. The only qualification that does not require flight operations is the no-load operations officer. However, even though it does not require flight operations, it does require that steam is provided to the catapults. When the CVN is in port, catapults are rarely provided with steam, so no-load operations are normally conducted while the CVN is underway. Ultimately, the only opportunity for a shooter to complete the requisite PQS is when a CVN is underway and conducting flight operations.

2.3 Launch Procedures

The procedures of launching an aircraft from the flight deck of a CVN are described in detail in the Naval Air Training and Operating Procedures Standardization (NATOPS) [1]. The two methods in which aircraft are launched are from the deck, known as a "topside" launch (Figure 2.1), and from the Integrated Catapult Control Station (ICCS), known as a "bubble" launch (Figure 2.2.) During a topside launch, the shooter is standing on the flight deck and directs the deckedge operator, via hand signals, to press the buttons which operate the catapult. In this type of launch, the shooter has direct interaction with the events on the flight deck, but limited control over the actual catapult operation. During a bubble launch, the shooter presses the catapult buttons himself but has limited interaction with the flight deck and must communicate his intentions via radio and a safety observer. With the exception of who is pressing the buttons, there is no difference in the launch procedure. The narrative of these procedures for launching an aircraft from the bow catapults is as follows:

Figure 2.1: Topside launch from USS *George H.W. Bush* (CVN-77) with shooter under instruction, from CVN-77 homepage [3]

The bow launch begins when the flight director signals the aircraft to be put into tension. He then passes control of the aircraft to the shooter. From this point on, if the shooter identifies anything out of the ordinary, he will signal to the deckedge operator to suspend the catapult. If no unusual situations present themselves, the shooter gives the military power signal to the pilot indicating that the aircraft engines should be put into the launching

Figure 2.2: ICCS on USS *Ronald Reagan* (CVN-76) from [4]

throttle position. Once the pilot completes his launch checks and is ready, he salutes the shooter. The shooter returns his salute and signals the deckedge operator to put the catapult into the final ready condition by raising his forward arm above his head. The shooter then conducts the launch scan as described above. Upon completion of the scan, the shooter touches the deck, and with deck pitch and interval timing under consideration raises his finger off the deck pointing towards the bow of the ship signaling the deckedge operator to fire the catapult. The aircraft launches and the process is repeated for the next aircraft.

If the aircraft does not launch even though the fire button was pressed, this is known as a hangfire condition and is indicated by the red fire light being illuminated, with no suspend light and the aircraft not launching. In this condition the catapult could fire at any time. This is an emergency and the shooter must follow the appropriate procedures. The actions taken by the shooter in the event of a hangfire are:

- Shooter gives the hand signal for suspend, which directs the deck edge operator to electronically safe the catapult
- Shooter then gives the hangfire hand signal to the deckedge operator
- The deckedge operator calls down to the catapult control room via sound powered phones and waits for confirmation that the catapult has been placed in a safe condition mechanically
- The deckedge gives the hand signal to the shooter indicating that the cat is safe
- The shooter then stands up and gives the pilot the throttle back hand signal directing

him to put the aircraft engines into an idle state

- The aircraft is then removed from tension

An unqualified shooter is required to perform launch procedures a minimum of 48 times under various conditions as outlined in the PQS [2] in order to become fully qualified.

2.4 Current Training

The requirement for a CVN to be underway, conducting flight operations, in order to conduct shooter training forces aircraft carriers that are in port or in the shipyard to take it upon themselves to find training opportunities for their shooters. They must coordinate with other aircraft carriers that are underway as part of their pre-deployment training cycle during phases requiring flight operations to train their own shooters. This situation has numerous challenges and is undesirable for several reasons.

First, the officers are being trained on a ship that may have different Standard Operating Procedures (SOP) and possibly a different configuration than the one to which they are assigned. For example, the USS *Harry S. Truman* (CVN-75) has four arresting gear engines and the outer panel of catapult number two Jet Blast Deflector (JBD) fouls (obstructs) the landing area. The USS *Ronald Reagan* (CVN-76) only has three arresting gear engines and catapult number two's JBD does not foul the landing area. A shooter from the USS *Harry S. Truman* training on the USS *Ronald Reagan* will have been trained with procedures that could lead to dangerous situations, such as declaring the landing area clear when the outer panel of catapult two's JBD is raised.

Next, it is a burden on the hosting command to train visiting officers. While being evaluated as part of a pre-deployment exercise, a command is under a great deal of pressure. Not only are they being evaluated on their effectiveness as a unit, but also on their training programs and personnel levels. Therefore, the hosting command will give higher training priority to their own personnel, specifically their shooters, enlisted monitors, and deckedge operators. If the monitor or deckedge operator is training, the visiting shooter will be unable to train due to the following NATOPS restriction "catapult shall not be operated when the launching officer and the monitor / deckedge operator are under instruction at the same time" [1].

Finally, most shooters are naval aviators and naval flight officers on a disassociated sea tour, after having recently completed a flying tour. They come from various aircraft platforms but all share the background of flight school and flight training, where the importance of training, and practice was emphasized. Naval aviators and naval flight officers conduct a large portion of their training and qualification in simulators and are familiar with learning new skills in simulation prior to practicing and demonstrating those skills in an operational environment. This allows for decreased time to train and lower cost. In order to train a shooter in as close as possible to the PQS estimated time to train of 18 weeks [2], commands maximize training opportunities by sending officers underway on any available carrier, which increases the burden on the officer under training by requiring them to spend weeks away from their command, and additional time away from their families in order to conduct training while their own ship is in port. This time, cost, and burden could be reduced if the officer was able to conduct training in a simulator, just as he would in a flying command.

CHAPTER 3:
Literature Review

This chapter explores research in the areas of skill acquisition, job task analysis, and virtual environments. The work discussed in this chapter forms the academic justification for the creation of the virtual shooter environment.

3.1 Skill Acquisition

Based on decades of research, Dreyfus and Dreyfus [5]–[7] developed a model consisting of five skill levels founded upon four mental qualities that an individual must pass through when learning a skill as shown in Table 3.1. These skill levels are: novice, advanced beginner, competence, proficiency, expertise. Within each skill level the mental functions required are components, perspective, decision, and commitment. The levels are described as such:

- Novice: A beginner who is given context free task features and a set of rules for determining actions to be taken based on the features.
- Advanced beginner: As the novice gains experience in actual situations, they develop an understanding of the context of the situation and begin to notice additional aspects based on this experience in combination with the non-contextual features previously learned.
- Competence: Increased practice has exposed the individual to more situational components and he can now recognize whole situations, which have meaning and relevance to the achievement of a long-term goal. The learner is able to prioritize the overwhelming number of potentially important situational aspects into those that are currently relevant and those that can be safely ignored and develop new rules that are based on their own experience.
- Proficiency: Upon reaching this stage, an individual becomes emotionally involved in the task and achieves intuition to discriminate between various situations and choose the appropriate action. Once this action is decided he falls back on the rule-based decisions to achieve the goal.
- Expertise: The individual's vast experience not only allows him to intuitively dis-

criminate between situations but also immediately know the actions that need to be taken in order to achieve his goal. This ability to make more subtle discriminations is what distinguishes expert from proficient performers.

Table 3.1: Five Stages of Skill Acquisition, from Dreyfus and Dreyfus [7]

Skill Level	Components	Perspective	Decision	Commitment
1. Novice	Context free	None	Analytic	Detached
2. Advanced beginner	Context free and situational	None	Analytic	Detached
3. Competent	Context free and situational	Chosen	Analytic	Detached understanding and deciding; involved outcome
4. Proficient	Context free and situational	Experienced	Analytic	Involved understanding; detached deciding
5. Expert	Context free and situational	Experienced	Intuitive	Involved

Note: Components: This refers to the elements of the situation that the learner is able to perceive. These can be context free and pertaining to general aspects of the skill or situational, which only relate to the specific situation that the learner is meeting. Perspective: As the learner begins to be able to recognize almost innumerable components, he or she must choose which one to focus on. He or she is then taking a perspective. Decision: The learner is making a decision on how to act in the situation he or she is in. This can be based on analytic reasoning or an intuitive decision based on experience and holistic discrimination of the particular situation. Commitment: This describes the degree to which the learner is immersed in the learning situation when it comes to understanding, deciding, and the outcome of the situation—action pairing.

Dreyfus and Dreyfus [5] stress that it is essential, when developing a training program, to determine the skill level that the trainee has achieved in order to be effective. If the training program is not at the appropriate level, the trainee will not progress to the next stage and may even regress to a previous level. For example, qualified officers undergoing training who have already completed schoolhouse shooter training, arresting gear officer qualification, and no-loads operator training from the shooter PQS, would be assessed to be at the "advanced beginner" skill level. These officers are able to recognize various situations and mentally determine the correct actions to take, however, they have little to no actual practice. They lack the rehearsed motor skills required to carry out a prescribed action and may not recognize unusual circumstances. According to the Dreyfus and Dreyfus model, this recognition will come with experience, practice, and exposure to varying situations.

It is relevant to note that Gobet and Chassy [8] criticize the Dreyfus and Dreyfus model. In particular, they disagree with the description of distinct phases and the attributes of expertise relying purely on intuition. Despite these criticisms, the Dreyfus and Dreyfus model is applicable to training situations in which the trainee is at the advanced beginner / competent levels as the individual in these stages still relies on decision making and rules instead of the intuition described at the expert level [8].

In 1988, Baldwin and Ford [9] reviewed the research on training effectiveness, specifically the transfer of training, defined as "the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in a training context to the job" [10]. This model identifies the interaction between training inputs, training outputs and conditions of transfer. Training inputs are trainee characteristics, training design, and work environment. Trainee characteristics include ability, personality, and motivation. Training design includes principles of learning, sequencing, and training content. Work environment includes support and opportunity to use learned behaviors on the job. The research conducted by Baldwin and Ford reinforces this thesis' hypothesis that skills learned in a training environment can be transferred to the job.

3.1.1 Training Fidelity

Baldwin and Ford note that a large portion of previous research focused on four basic principles, identical elements, teaching of general principles, stimulus variability, and various conditions of practice [9]. The principles of identical elements and stimulus variability are of particular importance for this thesis. The principle of identical elements consists of two aspects, physical fidelity and psychological fidelity. Physical fidelity is defined as "the degree to which the physical simulation looks, sounds, and feels like the operational environment in terms of the visual displays, controls, and audio as well as the physics models driving each of these variables" [11]. Psychological fidelity is defined as "the degree to which the simulation replicates the psychological factors (i.e., stress, fear) experienced in the real-world environment, engaging the trainee in the same manner as the actual equipment would in the real world" [11].

Stimulus variability is based on the notion that training is maximized when there is a variety of relevant training stimuli [9]. Shore and Sechrest [12] found that using a number of examples repeated a few times was more effective than using one example repeated many times. For example, a small number of launch scenarios, such as a normal launch, a suspend, and a wind out of limits event, changing throughout a few training sessions would be more effective than the exact same scenario, such as a normal launch, repeated over many training sessions.

Several investigations [13]–[16] demonstrate that the highest levels of positive training transfer, defined "as the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in a training context to the job" [9], is not based on fidelity, but rather the capacity of one part of the stimulus to cue the entire scenario. These findings are also supported by Alexander et al., who found that although the relationship between fidelity and transfer is complex, if the level of fidelity captures the critical elements of the task or skill that is desired to be taught, then the level of fidelity is sufficient even if the level of fidelity differs significantly from the real world [11]. This means that the required fidelity changes based on the type of training. These investigations show that even low fidelity training aids are effective in producing high quality training as long as there are strong and accurate cuing relationships between the scenario attributes and appropriate actions.

3.1.2 Presence and Immersion

Computer based alternatives to live training such as simulators, computer based training and even video games are becoming more common [10]. Alexander et al. [11] propose that knowledge transfer can be increased by manipulating four key concepts of the environment represented by the computer based system: fidelity, immersion, presence and buy-in. As previously discussed, fidelity consists of physical and psychological types.

Immersion refers to the degree to which an individual feels absorbed by or engrossed in a particular experience [17]. Many activities can be immersive, such as reading a book, playing chess, or watching a movie.

Presence refers to the experience of actually existing within the virtual environment [17], [18]. The difference between immersion and presence is the sense of physicality. When immersed in an activity a user remains aware of their physical location. When they have the sensation of presence in a virtual environment they experience the sensation that they are physically located in that environment.

Buy-in refers to the degree to which a person believes that an experience is useful to their training [11]. The concept of buy-in in this context is that the more useful a trainee feels the training environment is, the more effort they will put into learning within that environment. Likewise, if they feel that a training environment is not effective they will stop using that training device. Alexander et al. note that there is anecdotal, but not empirical, evidence that buy-in will affect transfer from simulation to operation if the amount of training remains constant [11].

Bacon and MacKinnon [19] showed that in order to build an effective virtual environment (in this case a serious game) the intended learning content must be fully embedded into the gameplay, and the environment must be immersive and engaging. Their study built on the work of others who demonstrated that with full immersion and engagement in the virtual environment, the subjects experienced positive transfer of training from the virtual environment to the real world.

3.2 Job Task Analysis

In a June 2012 Government Accountability Office briefing for the Senate and House Armed Services Committees [20], it was stated that "If a skill or talent can be developed or refined, or if a proficiency can be effectively and efficiently maintained in a simulator, then these skills/talents/proficiencies should be developed/refined/maintained in a simulator". Before a simulator can be developed to effectively answer the GAO's directive, the task to be trained must be thoroughly understood.

Naval education and training command has a manual entitled *Job Duty Task Analysis (JDTA) Management Manual* [21] which describes a process for analyzing the components required in order to accomplish an objective. Within this manual are the following definitions:

- An occupation is a family of jobs that share a common set of skills. In the Navy, an occupation is associated with a rating and is comprised of one or more jobs
- A job is composed of the duties, tasks, and steps performed by an individual. A job is comprised of one or more duties
- A duty is a set of related tasks within a job. A duty is comprised of one or more tasks, and occurs frequently
- A task is a single unit of specific work behavior with clear beginning and ending points
- A sub-task is a major part of a task and is made up of one or more steps
- A step is the smallest component in the process

By these definitions, launch officer is an occupation composed of various jobs which are outlined in the PQS. Following the JDTA process, jobs are broken down into tasks and steps. Specific skills are required in order to complete the various steps. Further, each skill can have one, all, or a mix of the following:

- Declarative Knowledge (DK), factual or experimental [22]
- Procedural Knowledge (PK), goal oriented and mediates problem solving [22]
- Situational Awareness (SA), what is happening in the vicinity [23]

In the case of this thesis, declarative knowledge is the academic knowledge of the physical systems known as Aircraft Launch and Recovery Equipment (ALRE). The PQS lists completion of Shooter School as a prerequisite for every watchstander qualification. Shooter School consists of a formal systems training course where the officers are taught the catapult and arresting gear systems. In addition to shooter school the PQS also requires that the officer understand the operation of the systems prior to qualification. This academic knowledge of system operations ensures that the launch officer understands what is happening to the equipment and it ensures that he can enforce the execution of proper procedures.

Procedural knowledge is the memorization and understanding of the procedures outlined in the PQS, SOPs and governing instructions, and is represented by the ability of a qualified shooter to recognize abnormal conditions immediately and carry out the proper procedures at all times. Procedural knowledge is directly impacted by experience. An experienced shooter can recognize the first indication that an abnormal procedure is developing and then take the appropriate action to either mitigate or prevent that situation from developing further. For example, they might notice that as an aircraft is approaching the catapult something does not look the way that it has looked on similar aircraft based on their experience. The shooter can bring this to the attention of the final checker to determine if the aircraft is properly configured. The shooter can then proceed to launch or turn it away prior to pre-launch checks on the catapult.

Situational awareness is understanding what is happening around you, and being aware of how the situation is progressing based on your knowledge and experience. For this thesis, the definition used for Situational Awareness is provided by Mica Endsley as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status into the near future" [23].

Endsley describes three levels of situational awareness. Level one is the perception of elements in the current situation. Level two is the comprehension of the current situation. Level three is the projection of future status. As one progresses through the skill levels described by Dreyfus and Dreyfus, they should also move along the situational awareness levels described by Endsley.

One aspect of SA as it pertains to this thesis is visual observation. Visual observation is defined as the shooter physically looking at various areas of the flight deck. He is visually verifying that the ALRE equipment is in the proper operating condition, the expected type of aircraft is in the landing pattern, the aircraft approaching the catapult is in the correct configuration, and the personnel on the flight deck are in the proper positions. The amount of information recognized as the shooter is observing the areas of the flight deck will change as they increase through the levels of SA. For example, a shooter with level one SA will observe that there is a person standing outside the safe-shot line and continue with the launch because no rules are being violated. The shooter with level two SA will recognize that the person in question is part of the safety officer tour. Finally, the shooter with level three SA will recognize that this person is not only part of the tour, but also separated from the rest of their group and will most likely cross the safe shot line in the near future in order to get back to their friends.

3.3 Virtual Environments

According to Ellis, virtual environments can be defined as "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space." [24]. There are many methods of using computers to simulate environments, of particular interest to training simulation are Virtual Reality (VR), AR, and Mixed Reality (MR). Virtual Reality completely immerses a user inside computer generated 3D environment. While in this environment the user cannot see the real world [25]. Augmented Reality provides computer generated objects and information overlaid onto the user's view of the real world [25], [26]. Mixed Reality is the varying mix of real and virtual elements as shown in Figure 3.1 [27]. If one were to take the spectrum of reality from completely virtual on one end to completely real on the other, it would be called the mixed reality continuum [26] and in it AR lies in between the two extremes [28]. Essentially, VR replaces the real world where AR enhances it.

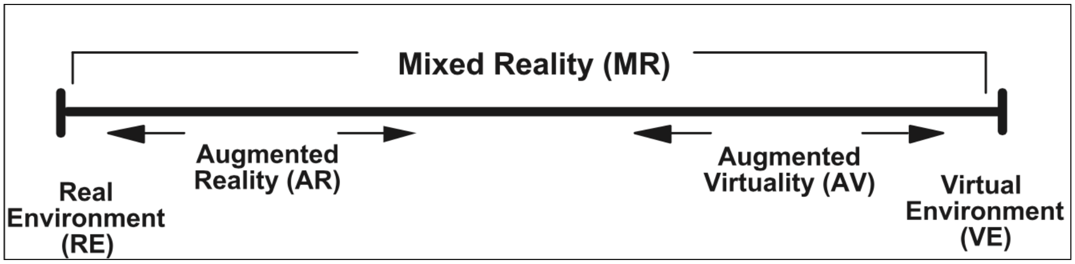

Figure 3.1: The mixed reality continuum, from Milgram [27]

3.3.1 Virtual Reality

Virtual reality is a popular training technology. The types of VR systems used are projection systems such as the Cave Automatic Virtual Environment (CAVE) system which uses stereo surround sound and projected 3D computer images onto screens that completely surround the user [29], full simulator systems which reproduce a vehicle and then project or display the environment on screens or monitors, and immersive head mounted display systems where the entire environment is presented via a device worn on the head of the user.

Applications of VR

Military simulators are an example of practical application of VR. They place the user into an entirely computer-generated environment. The user interacts with the environment from within a physical reproduction of the vehicle they will be operating (aircraft, tank, High Mobility Multipurpose Wheeled Vehicle (HMMWV), etc.) A completely virtual environment is projected on screens outside the vehicle and inputs are sent to the systems inside the vehicle [30], [31]. However, there are other types of VR that are also employed, such as the Landing Signal Officer (LSO) trainer at the LSO School in Virginia Beach [32]. This trainer uses a CAVE display system with a simulator type platform to train landing signal officers in directing aircraft to land on the deck of an aircraft carrier. Additionally, head mounted displays have been used to train individuals for specific dangerous tasks such as parachute jumping [33], where the trainee can practice parachuting skills prior to an actual jump, and for small unit infantry training such as the Future Immersive Training Environment (FITE), system where a soldier can train his infantry skills.

3.3.2 Augmented Reality

Types

Azuma [25] defines AR as any system that has the following three characteristics:

1. Combines real and virtual
2. Is interactive in real time
3. Is registered in three dimensions

By this definition AR is not limited to any particular type of technology. Currently, AR is being used on many different platforms. These include smart phones, head mounted displays, desktop and laptop computers, and specialized technology such as amusement park rides [34]. Despite the differing platforms, AR is classified into three broad areas: headworn, handheld, and projected [28].

Headworn displays are devices worn on the head which present content directly in front of the user's eyes and can be divided into two main types: optical see-through, and video see-through. In optical see-through the user is looking through a transparent medium with the virtual images displayed via some form of technology such as a waveform, prisms, or transparent light field matrix [25], [28], [34]–[40]. In video see-through, the user is looking at the real world as captured by cameras with the virtual objects integrated into the scene and displayed on opaque screens in front of their eyes.

Handheld displays use a Liquid Crystal Display (LCD) or Organic Light-Emitting Diode (OLED) screen such as those found on a smart phone or tablet with an attached camera to display a video see through experience to the user. An example of this type of augmented reality is the IKEA augmented reality application that allows a potential buyer to visualize how furniture from the IKEA catalogue would look in their own home (Figure 3.2) [41].

Projected displays use projectors to present virtual information into the area around the user. One example of the use of this type of display is the immersive environments created in the Disney themeparks [42]. For example the "Haunted Mansion" attraction at Disney World for which virtual ghosts are projected into the ride (Figure 3.3.)

Figure 3.2: IKEA catalogue AR application, from Metaio [41]

Applications of AR

The number of commercial applications for AR is increasing rapidly. By looking on the Apple App Store or Google Play marketplace there are a large number of AR applications for smartphones and tablets for marketing, advertisements and entertainment. Disney also employs AR for entertainment purposes in many of its attractions. While these applications are interesting, they do not represent the full potential of AR. Metaio has provided a system to Volkswagen called Marta [43] to help develop the XL1 concept car and it built applications for Mitsubishi to assist their sales associates by allowing them to show customers what their heating and air conditioning units would look like in the customers own home. They also provide AR applications to the manufacturing industry for factory layout, prototyping, and training. SCOPE AR, in a popular training demonstration, uses augmented reality to overlay the steps of a repair on the actual piece of equipment that is being worked on [44] In museums such as the Bavarian National Museum, AR enhances the exhibits. When viewed through the AR application on a visitor's smart device, details of interest, additional views of the piece of art, or overlays of the original setting in which the piece was presented historically [45] are presented to the viewer.

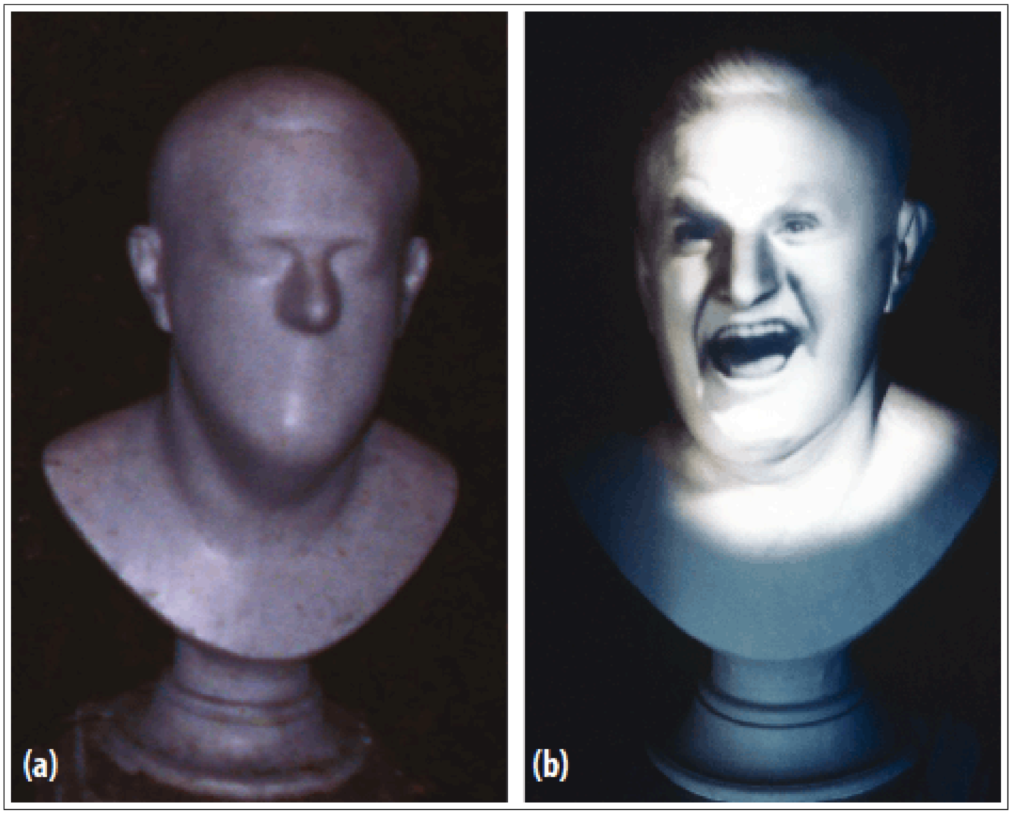

Figure 3.3: Singing bust from the Haunted Mansion graveyard without (a) and with (b) AR, from Mine et al. [42]

As with the commercial sector, there are many potential military applications of AR. Military aircraft have had heads up displays since the 1960s [46] and NASA studied using heads up displays for taxiway navigation [47] and many other applications. Currently, a projection-based Mixed Reality system is installed at the Infantry Immersion Trainer in Camp Pendleton, a binocular AR system has been tested for use in forward observer training [48], a C-130 loadmaster training AR application was developed and tested [49], and Applied Research Associates recently finished testing of the Ultra Vis AR system for the dismounted soldier [50]–[52].

3.3.3 Mixed Reality

When attempting to reproduce experiments with AR systems, researchers had difficulty replicating the exact conditions encountered during the original experiments, such as outdoor environmental conditions [53]. This has led to research in the area of Mixed Reality, specifically, the work of Lee et al. [53]–[56] in testing various AR systems inside a VR environment. The advantages to this technique include a controlled environment that can be reliably reproduced, and the ability to simulate hardware characteristics of different AR devices accurately without having access to the physical equipment. Lee et al. showed that testing and representation of AR devices in VR is possible by successfully recreating a well-known AR experiment originally performed by Ellis. In this experiment virtual rings were manipulated along virtual ropes overlaid on the real world via a head mounted display. Lee and his team created a virtual world with a virtual hand and a simulated AR view that was consistent with the optical see-through device used in the original experiment and achieved comparable results.

3.3.4 Current Technology

Current technology in virtual environments consists of a computational platform and displays. The desktop computer and monitor can provide a virtual environment as demonstrated by commercial games such as World of Warcraft and Second Life. This type of virtual environment could be both low cost and deployable. Virtual Reality head mounted displays include the Oculus Rift which is attached to a personal computer and provides the user with 960x1080 display for each eye with a 100 degree field of view [57]. The ZEISS VR One, and Google Cardboard provide a head mount to hold a smart phone such as the iPhone 6 or Samsung Galaxy S5 as the computational and display platform [58], [59]. The lenses in the mount give an expanded field of view by distorting the display, but exact numbers vary based on the lenses used. The range is anywhere between 90-100 degrees based on various technology websites. Handheld AR technology primarily consists of smart phones with cameras running either iOS or Android operating systems that provide video see-through AR experiences. AR head mounted displays have a more limited availability, although many have been announced one of the few available is the EPSON Moverio BT-200 which provides both optical and video see through capability with a 23 degree field of view [60].

3.4 Chapter Summary

In summary, using virtual environments to achieve training transfer which results in the acquisition of skills is a complex combination of factors. Analysis of the desired tasks to be trained and skills to be learned are essential to identifying the right balance of these factors in the development of a training environment. The hardware, which generates the environment will also impact the virtual environment based on the methods of its presentation. When determining which device should be used, practicalities such as cost and development time must be considered and can have a considerable impact on identifying the correct device.

The next chapter describes the methodology used to determine which tasks are required for the shooters to perform the duties of the various watchstations, the approach used to model these tasks in a manner that is executable on current computational equipment, and which current technologies are best suited to realize that model.

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER 4:
Methodology

4.1 Job Task Analysis Methodology

The JDTA process as described in [21] was followed to deconstruct the launch officer job and determine the relevant tasks. With the understanding that declarative knowledge is required for all jobs, an assessment was made to determine which skills and sub-tasks were required for each watch station task and whether these skills were suitable for representation in a virtual environment, defined by Ellis as "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space" [24]. In order to identify the tasks with the greatest potential advantage for training and proficiency in a virtual environment, each task was examined and assigned a level of Difficulty, Importance, and Frequency (DIF) which would be used to rank the tasks.

4.2 Programming Methodology

An evaluation of the enablers and detractors for developing a virtual environment to conduct these tasks was performed in order to identify the difficulty and feasibility of creating an appropriate environment using a top down programming approach. The top down programming approach is similar to the job task analysis in that the problem is broken into subsequently smaller items until each of these items can be performed on the computational equipment available.

4.3 Analysis of Alternatives

There are a number of different technologies available to construct a virtual environment. The factors considered for choosing the technology used included hardware and software, cost, portability, and ease of programming. As discussed in Chapter 3, the technology would consist of a computer system, a software package, a head-mounted display and an input device.

4.3.1 Hardware

The selection of low-cost head-mounted displays is limited, and the analysis focused mainly on cost and availability. The virtual environment could be useful for both training and proficiency. In order to accommodate both of these areas the hardware required for input devices was evaluated for ease of use for both instructors and users of the systems while minimizing the negative impact to immersion and presence.

4.3.2 Software

Six software development engines were considered for the development of the virtual environment. The software was evaluated based on operating system upon which it ran, whether it has built-in Oculus Rift support, cost and ease of use. The software that was considered largely fell into the game development engine categories due to commercial interest in utilizing head mounted displays in game development. One non-game engine virtual reality software package was evaluated alongside the game engines.

4.4 Chapter Summary

This chapter discussed the methods for determining the tasks required in the performance of the shooter duties, how these tasks were analyzed in the context of programming them in a development engine, and finally, which hardware and software will be used in the development of the virtual environment. The next chapter presents the findings of this analysis and the resulting virtual environment.

CHAPTER 5: Evaluation

5.1 Job Task Analysis Results

The results of the job task analysis are presented in table 5.1 and indicate that the watchstation with the potential for most training impact is the Launch Officer watchstation. The PQS separates the Launch Officer qualification into two distinct qualifications, bow launch officer and waist launch officer. Within the launch officer qualification, the most important task identified in Table 5.1 by having a “high" on all DIF areas was the scan for both the bow and waist. The scan patterns for bow and waist launches differ slightly, however, both scans consist of the same steps with the primary difference being where the items within the steps are physically located in relation to the shooter. Thus, the task analysis evaluation found the bow launch scan as the best-suited scenario for representation in the virtual environment. Additional tasks in the watchstation such as aircraft configuration and aircraft hookup and alignment can be added to the scenario for additional benefit.

From the launch procedures and JDTA, the following steps required during the launch officer scan were identified as essential for reproduction in the virtual environment:

- Visually observe bow safety light is green
- Visually observe deck edge has hands up and lights
- Visually observe three white catapult status lights are illuminated
- Visually observe that the suspend light is not illuminated
- Ensure headwind is within acceptable limits
- Ensure crosswind is within acceptable limits
- Visually observe the landing pattern is clear
- Visually observe the status of the other launch officer to determine catapult interval
- Visually observe the aircraft final checker giving a thumbs up signal
- Ensure aircraft pilots head is steady
- Visually observe deck pitch and signal launch according to SOP

Table 5.1: Shooter Job Task Analysis Results

Qualification	Task	Skills			Can Be Simulated	Simulation Requirements	Enablers	Detractors	D, I, F	Suitable
		Visual Observation	Declarative Knowledge	Situational Awareness						
AGO	Aircraft Identification: Day	X			Yes	High enough fidelity to pick out characteristics of aircraft. Biggest challenge: differentiating between F/A-18 C, E, F, G	Relatively easy to simulate with apprpriate models. Intakes are one of the primary indicators of AC type	Persistence, if integrated into a landing scenario. This task is one small task in the AGO task list.	D: Low (2) I: High (5) - has mulitple backups F:High (6) Every landing and touch and go	Yes
	Aircraft Identification: Night	X			Yes	Light configurations are the only requirement.	Easy to simulate. Don't even need a model Can be accomplished without simulation	Persistence, if integrated into a landing scenario. This task is one small task in the AGO task list.	D: Low(1) I: High (5) - has multiple backups F: High (6) Every landing and touch and go	No
	Recognition of conditions that prevent a clear deck	X			Yes	Flight Deck Landing Area Parked Aircraft People walking, moving around LA JBD up/down (CAT 2) AC on CAT 2, wings folded/spread PO forward Clear/Foul Light LSO Platform	Relatively low amount of head movement. Easier to simulate than a launch	Registration and tracking. There may or may not be enough fidelity to enable markerless tracking, but markers may be used. If done on actual flight deck in port, storage and work may be going on in the LA, leading to unrealistic scenarios for AR. AGO is not the qualification that usually delayed.	D: Low (2) I: High (5) F: High (6) Every landing and touch and go	Yes
	Calculation arresting gear settings for abnormal landing configuration		X	X	No					No
	Recognition of in-flight engagement	X		X	Yes	Flight Deck Landing Area Parked Aircraft People walking, moving around LA JBD up/down (CAT 2) AC on CAT 2, wings folded/spread PO forward Clear/Foul Light LSO Platform	Relatively low amount of head movement. Easier to simulate than a launch	Registration and tracking. There may or may not be enough fidelity to enable markerless tracking, but markers may be used. If done on actual flight deck in port, storage and work may be going on in the LA, leading to unrealistic scenarios for AR. AGO is not the qualification that usually delayed.	D: Medium (4) I: High (7) F: Low (1) Occurs infrequently. There was one instance of possible IFE during my entire tour, but it turned out to not actually be an IFE	Yes
No - Loads	Systems/Procedural knowledge		X		Yes	Shot Line (people holding rope/wands) Center Deck / CSV settings Deck Edge lights TSPO (to break tension) Shuttle	No Aircraft Models required Easier to simulate than a full launch No launch bulletins required	This doesn't have a real need to be simulated. Actual No-Loads can be performed in port or at sea without an airwing.	D: Low (1) I: Medium (5) This qualification is mostly focused on system study not performed on the flight deck. F: High (6) No Loads are required to be performed prior to flight operations every day.	
Launch Officer	Bow Scan	X	X	X	Yes	Center Deck / CSV Bow Light Beacon Shuttle TSPO Weight Board (JBD Operator) JBD Final Checkers Aircraft with Pilot Deck Edge lights and PO Pattern Aircraft (possibly) Aircraft on other CATS (possibly)	Most to gain by simulating this Most time lost during the launch officer qualification phase (bow and waist) Currently requires underway with aircraft Can simulate launch emergencies currently not trainable	Persistence: Scan involves moving head around rapidly and looking at many different areas Registration: Due to head movement Many Models required Difficult to build environment	D: High (5) I: High(6) F: High(7) Every launch	Yes
	Waist Scan	X	X	X	Yes	Center Deck / CSV Waist Light Beacon Shuttle TSPO Weight Board (JBD Operator) JBD Final Checkers Aircraft with Pilot Deck Edge lights and PO Pattern Aircraft (possibly) Aircraft on other CATS (possibly)	Most to gain by simulating this Most time lost during the launch officer qualification phase (bow and waist) Currently requires underway with aircraft Most difficult qualification to achieve Can simulate launch emergencies currently not trainable	Persistence: Scan involves moving head around rapidly and looking at many different areas Registration: Due to head movement Many Models required Difficult to build environment	D: High(6) I: High(6) F: High(7) Every launch	Yes
	Aircraft hookup / alignment	X	X	X	Yes	TSPO Aircraft with detailed nosewheel Shuttle	Easier to simulate than a full launch. Part of the launch sequence, so scalable Minimal head movement	Normally first noticed by TSPO Better simulated as part of the launch	D: Low (2) I: High (5) F: High(6) Every launch	Yes, but should be incorporated into a full launch scenario
	Wind / CSV computations		X	X	No					No, able to be accomplished below decks with a notebook.
	Aircraft Configuration (wing locks, flaps settings, external stores, panels/pins)	X	X	X	Yes	Shuttle TSPO Final Checkers Aircraft with different configurations (Flaps/Struts/WPNS)	Get to recognize configurations prior to real world Minimal head movement	Configurations could be shown as pictures instead of in simulation Better simulated as part of a full launch scenario	D: Low (2) I: Medium(4) F: High (6) Checked every launch	Yes, but should be incorporated into a full launch scenario
	Launch sequence plan	X	X	X	No					
	Pitching deck	X	X	X	Yes	Center Deck / CSV Bow/Waist Light Beacon Shuttle TSPO Weight Board (JBD Operator) JBD Final Checkers Aircraft with Pilot Deck Edge lights and PO Pattern Aircraft (possibly) Aircraft on other CATS (possibly)	Positive training gains by simulating Currently not explicitly trainable, only when encountered in real life.	Can only be done as part of a full launch scenario, so all detractors from launch apply. Recognition of a pitching deck without a launch is trivial. Each catapult on each ship is different - timing would be an issue	D: Medium (4) I: High (7) F: Medium (3): Ships try to find calm seas for launch, but calm seas are not always possible.	Yes, but should be incorporated into a full launch scenario
	Bow interval cyclic ops	X	X	X	Yes	Part of Bow Scan	Part of Bow Scan	Part of Bow Scan	Part of Bow Scan	Yes, but should be incorporated into a full launch scenario or scan scenario
	Bow interval CQ	X	X	X	Yes	Part of Bow Scan	Part of Bow Scan	Part of Bow Scan	Part of Bow Scan	Yes, but should be incorporated into a full launch scenario or scan scenario
	Waist interval cyclic ops	X	X	X	Yes	Part of Waist Scan	Part of Waist Scan	Part of Waist Scan	Part of Waist Scan	Yes, but should be incorporated into a full launch scenario or scan scenario
	Waist interval CQ	X	X	X	Yes	Part of Waist Scan	Part of Waist Scan	Part of Waist Scan	Part of Waist Scan	Yes, but should be incorporated into a full launch scenario or scan scenario

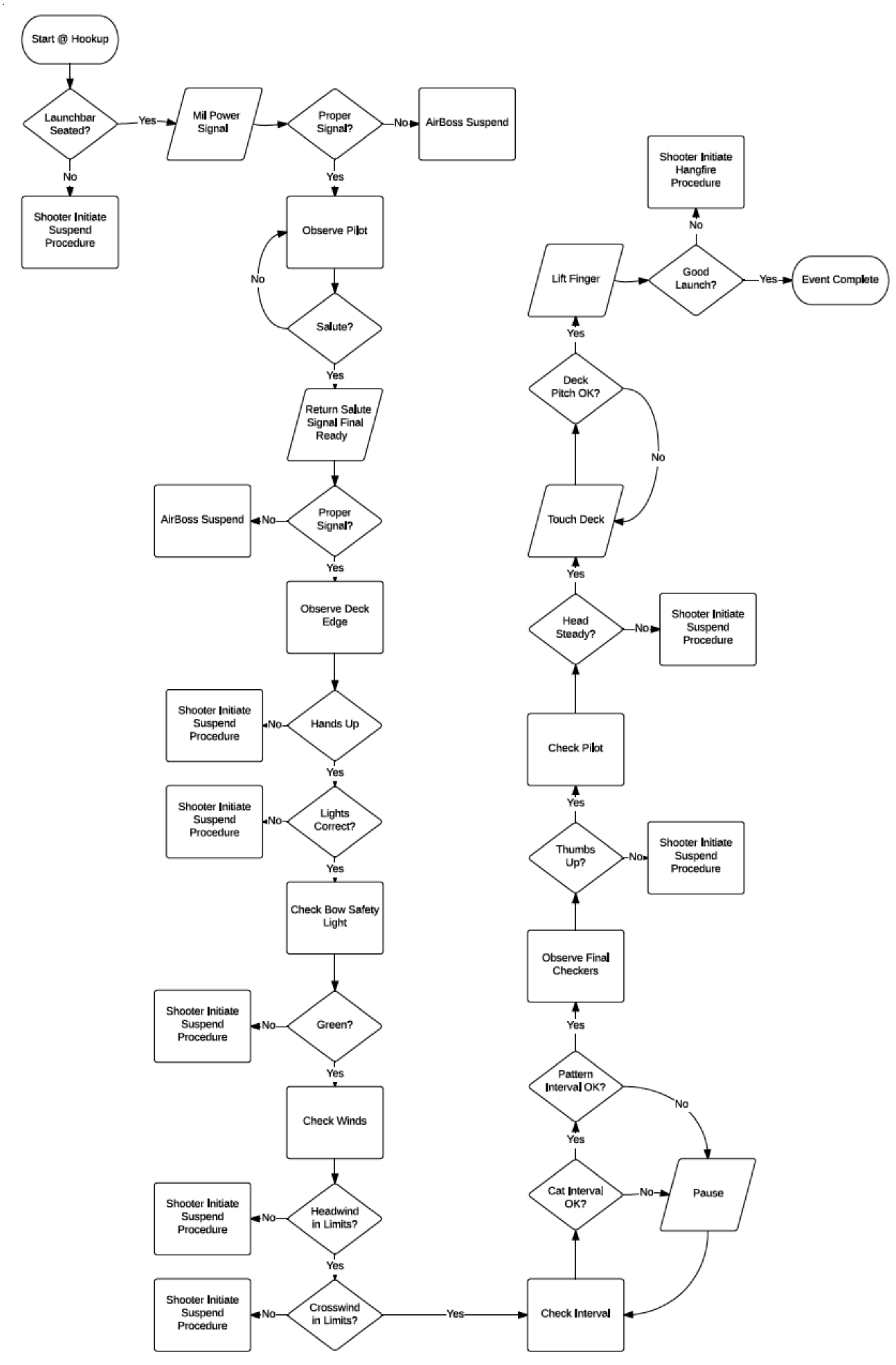

Figure 5.1: Launch Flow

The bow scan tasks were further broken down into steps which are represented in a flowchart format shown in Figure 5.1 Using the flowchart and task analysis, a Finite State Machine (FSM) was developed to represent the flow of events based on the catapult system status (Figure 5.2) This FSM was the model for the development of the virtual environment.

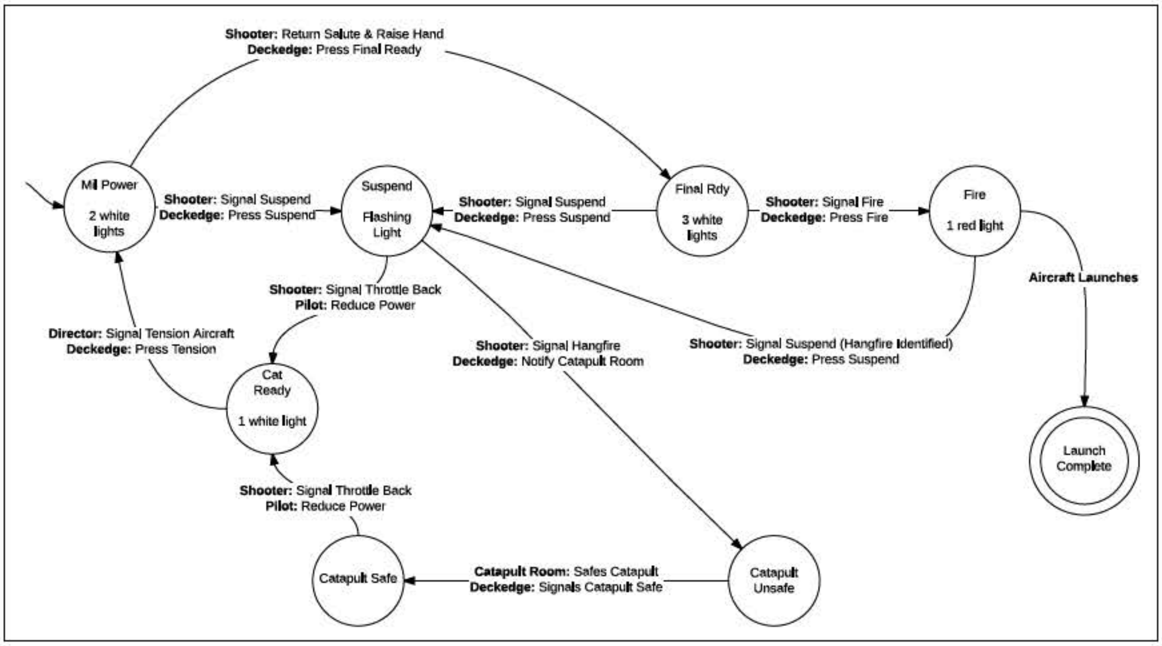

Figure 5.2: Launch Finite State Machine

5.2 Development of the Virtual Environment

Evidence from Chapter 3 supports the possibility to transfer knowledge and training skills from a virtual environment to the physical world if the virtual world has adequate immersion, presence, fidelity, and buy-in.

The main elements identified for programming the environment during the programming methodology described in Chapter 4 were:

- Input: predefined scenarios, instructor injects, user input
- Actions: computations, timing events, variable manipulation
- Output: environment display, reports, timing results

These elements are taken into consideration when evaluating the results below to create the most effective virtual environment.

5.2.1 Hardware

As described in Chapter 2, the flight deck is a dynamic environment and the launch officer is scanning the area while simultaneously using both of his hands to signal others on the flight deck. A video see through system such as one generated by a smartphone or tablet has limited utility because it requires the use of at least one hand to hold the display. Holding a screen while performing dynamic hand signaling would likely break immersion and presence. Similarly, head mounted AR devices do not provide a field of view large enough to present the user with the immersive experience necessary for a dynamic environment that requires constant scanning. Further, head mounted AR devices suffer from tracking and registration issues, limited computational power, and only allow for a single person to see the environment at a time, thus limiting the instructor input. For these reasons the most promising systems for which to develop the proposed virtual environment are the desktop computer environment and a head mounted virtual reality system. Both systems have the computational power of a modern desktop computer which is upgradeable in the future. Both systems allow for the instructor to observe the trainee via the computer monitor, and inject variables if desired. The head mounted system provides an immersive experience with a larger field of view and without the tracking and registration issues that could impact an AR system. These systems are also both low-cost and deployable.

In order to support a majority of computer systems available to the fleet, as well as current head mounted displays and software development considerations, the hardware required was determined to be a modern generation desktop or laptop computer. The hardware utilized for this thesis was a 2012 Apple Macbook Pro with a 2.6 GHz Intel i7 processor, 8 GB RAM and a discrete NVIDIA GeForce GT 650M graphics card.

The evaluation of head mounted displays was quickly narrowed to the Oculus Rift (Figure 5.3.) It is low cost ($350), easily available, and due to growing commercial interest, has built in support for many software development platforms.

For interaction with the virtual environment via the computer and a monitor either the keyboard and mouse, the wii controller (Figure 5.4), or a traditional game controller can be used.

Figure 5.3: Oculus Rift HMD

Figure 5.4: Wii Controller

5.2.2 Software

In order to maximize the potential usability of the system, the analysis determined that the software must be able to run on current Apple and Windows computational platforms, and provide built in support for the Oculus Rift. The results of this evaluation are presented in table 5.2.

All systems evaluated supported the Oculus Rift. All but one of the systems had a free option but only two were available on Apple OSX, Unity and Unreal Engine 4. Each of these game engines are widely used and have an active user community to provide tutorials and answer questions. However, the Unity engine was used in Naval Postgraduate School (NPS) Class MV4501 and is supported by the staff at NPS. Based on cost, platform support, and familiarity, Unity was selected as the software development environment.

Table 5.2: Software Comparison

Software	OSX	Windows	Oculus Support	Cost
Unity	X	X	Yes	Personal Licence: Free Unity Pro Licence: $1500
UDK		X	Yes	Non-commercial educational use: free Commercial Use: $99 + 25% of earnings after the first $50, 000
Unreal 4	X	X	Yes	Free + 5% royalty on revenue over first $3000 calculated per quarter.
Cry Engine		X	Yes	$9.90 / month
Torque 3D		X	Yes	Free and open source
Vizard 5		X	Yes	Free: minimal features Lite: $79, limited features Development: $3990.00 Enterprise: $5990.00

5.2.3 Virtual Environment

The virtual environment developed is an interactive flight deck. The user is placed standing between the bow catapults (Figure 5.5) and directs the actions taken as if they were on the flight deck conducting launch operations from catapult number one. In order to provide immersion and presence, the environment is presented in the first person point of view for both the desktop and head mounted display options.

Figure 5.5: Starting Position

There are three main forms of trainee interaction with the virtual environment.

In the first form of interaction, the trainee is wearing a head mounted display and directing the instructor to operate the system via hand signals, just as if the trainee were on the flight deck signaling the deckedge operator. This allows the trainee to perform all hand signals just as they would on the flight deck as well as providing the feeling of not actually controlling the status of the catapult and relying on the visual cues provided in the virtual environment.

In the second form of interaction, the trainee is wearing a head mounted display and utilizing the wii controller to interact directly with the virtual environment. This allows the trainee to practice proficiency without an instructor. In this setup the trainee can perform hand signals in a slightly modified manner, similar to those used when signaling with wands, as if conducting a night launch operation.

In the third form of interaction, the trainee is seated at a computer using the keyboard and mouse or a game controller. This form allows for practice when a head mounted display is unavailable or when instruction is desired to be given to a group of trainees by an instructor. Hand signals cannot be used in this configuration.

Following Baldwin and Ford's recommendation for stimulus variability [9], a variety of launch options are available to the trainer who selects the type and number of launch events that they desire to train in the virtual environment. This is accomplished via a simple text file that is loaded into the program on start and allows for a pre-planned and repeatable training scenario. The simple text file requires three fields for each scenario: the type of launch, the headwind, and crosswind. The type of launch can be one of the following while the training simulation is running:

- "regular" : a normal launch with no unusual circumstances
- "suspend" : a launch that will be suspended by the airboss
- "hangfire" : a launch that will end with a hangfire
- "badcheck" : a launch that will be suspended by the final checker
- "pitching" : a launch with a pitching deck

Additional flexibility is provided by giving the instructor the ability to inject or modify the following scenario elements:

- inject an airboss suspend
- inject a final checker suspend
- inject a pilot suspend
- inject a hangfire
- modify the color of the bow safety light to red
- modify the headwind
- modify the crosswind
- modify the deck pitch (on or off only)

The variables that comprise each step of the bow launch scan are measured by the program recording the amount of time the objects that need to be evaluated in Section 5.1 are observed by the user. This observation determination is made by sphere-casting, which is projecting an invisible sphere of radius 0.9 from the users center of vision forward until it intersects a collision box, which is an invisible box around the intended objects, that detects when the sphere impacts the box. Future testing may identify the need to re-size the collision boxes or the sphere radius to improve accuracy. The starting and ending values of both the headwind and crosswind are also recorded for each launch scenario.

This data is presented to the user on screen at the completion of the scenario (Figure 5.6) as well as saved to file for debriefing, record keeping, and trend analysis.

Figure 5.6: Completion Report

CHAPTER 6: Conclusions and Future Work

6.1 Conclusion

This research demonstrated that current launch officer training conducted solely via on-the-job performance in an under instruction status leaves training methodologies unexplored that have been shown to be beneficial. The research conducted on training transfer techniques and the job task analysis performed on the launch officer occupation support the claim that a virtual environment can provide the necessary elements needed to learn and practice skills required to perform launch officer tasks.

This thesis set out to answer four main research questions. Through research and building of the virtual environment evidence has been found that suggests all of the questions have been sufficiently answered. The questions and results are briefly summarized here.

1. What are the main skills required for an officer to qualify as arresting gear officer, bow catapult officer, and waist catapult officer that can be developed in a virtual environment?

   Through the task analysis conducted with techniques from the job duty task analysis, the main skills required as annotated in Table 5.1 were system knowledge, procedural knowledge, and situational awareness.

2. Based on current training literature, which of these skills can likely be trained effectively in a virtual environment?

   Chapter 3 explained that skills and knowledge can be learned in a virtual environment and then transferred to the physical world if the virtual environment has an adequate immersion, presence, and buy-in from the user [9], [11]. The shooter skills required for all tasks and knowledge learned through book study and classroom instruction was determined to be declarative knowledge of the system. The prototype that was built reinforces this declarative knowledge but does not focus on it. The literature shows that declarative knowledge can be trained effectively in a virtual environment, however, the one built in support of this thesis, assumes that a base level of system knowledge would be acquired prior to training with the virtual environment. Empirical evidence [19] supports that the other three skills can effectively be trained in a virtual environment like the one developed in this thesis. The objective and subjective effectiveness of this prototype environment in comparison to the current training methods have not been tested and are areas for future work.

3. What are the technical attributes a system needs to adequately represent the shooter environment for training?

   The technical attributes of a system should be based around the concepts of providing immersion, presence and buy-in. As shown in the research, a system must have a level of fidelity high enough to immerse the viewer in the virtual environment and that environment must be realistic enough to convince the viewer that he is present in that environment. The system built provides immersion and presence through the high definition head mounted display and flight deck environment created with detailed 3-dimensional models. The level of buy-in from the user for this system can be determined with future human testing. The buy-in aspect as discussed in prior work is a subjective element specific to each user. Since the intended user is a flight deck professional, something represented inaccurately, such as the final checker model may be enough to influence buy-in in a negative way. Future human testing must be performed in order to measure these attributes.

4. Do current and emerging systems possess the requisite attributes for use in a shooter training environment?

   Technology is rapidly advancing in the realms of virtual and augmented reality. The evidence supports that the current systems do in fact possess the requisite attributes to allow for a shooter training environment and the capabilities of the systems will continue to become more advanced. Current systems on the market can provide a low cost, deployable system that can provide a shooter environment with enough fidelity to serve as a shooter training tool.

By constructing a virtual environment that not only fills the requirements necessary to perform the tasks and skills identified in the job task analysis, but is also deployable in a low-cost and portable form factor, the fleet is one step closer to increased training and proficiency with reduced cost, risk, and timeframe.

6.2 Future Work

This thesis shows that it is possible to construct a virtual flight deck environment that can provide the scenarios required to practice the skills for launching aircraft from the CVN. What it does not show is how effective the provided virtual environment is for training unqualified shooters in their tasks or how effective it is in allowing already qualified shooters to practice their skills to maintain proficiency. This thesis is a first step towards realizing a carrier deployable simulation environment for flight deck personnel, however, in order to realize that goal additional research is required.

6.2.1 Human Testing

Although this thesis presents a virtual environment that provides the elements required to perform the tasks required of the launch officer, the effectiveness of the environment in a training construct was not conducted. Future work should develop a testing plan to measure the training effectiveness with a group of unqualified shooters using this system against a control group not using this system. The measures of effectiveness could be the unqualified shooters performance on their qualification boards and the time required to train before they felt that they were ready for their boards. Additionally, the environment could be tested with qualified shooters in various stages of the inter-deployment timeline to gauge the effectiveness for maintaining proficiency.

6.2.2 Display Type

This thesis provided a virtual environment presented in two formats, the desktop and virtual reality with no testing to determine which environment is more effective. Future work should investigate the difference in effectiveness between the head mounted display environment and the desktop environment. While this thesis focused only on whether a virtual environment was feasible for training it treated all virtual environments as equally effective which may or may not be the case. The results of this research will shape the future development of the training system for possible deployment to the fleet.

6.2.3 Eye Tracking

The virtual environment that was developed for this thesis relied on sphere-casting to determine the amount of time the user was observing the relevant objects in the environment. Future work should incorporate eye tracking technology within the selected display to more accurately track where the user was focusing their attention.

6.2.4 Augmented Reality

At the time of this thesis, the AR technology was not adequate to build an AR environment for training launch operations on an actual flight deck. With the advancements of low cost commercially available AR systems, future work could build and compare the differences in effectiveness of an AR system to VR systems like the one presented here.

APPENDIX A:
LaunchPlan.txt Example

```
regular
22.3
10.8
hangfire
30.3
5.8
suspend
28.8
3.5
```

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B:
Results Report Example

```
#Shooter: LT Shooter    DTG: 2015-03-06 08:36:54
Event # Type    Bow Safety      Deckedge        Windgauge       Interval        Final Checker   Pilot

Event 1 regular         1.63            8.00            5.85            4.62            2.85            18.92
        Initial HW: 22.3        Initial CW: 10.8
        Launch HW: 22.3 Launch CW: 10.8
Event 2 regular         0.20            14.18           6.03            2.33            3.93            18.08
        Initial HW: 22.3        Initial CW: 10.8
        Launch HW: 22.3 Launch CW: 10.8

Instructor Injects

************************ END OF REPORT ************************
```

THIS PAGE INTENTIONALLY LEFT BLANK

List of References

[1] *CVN Flight/Hangar Deck NATOPS Manual*, NAVAIR 00-80T-120, Naval Air Technical Services Facility, 2010.

[2] *Personnel Qualification Standard for Aircraft Launch and Recovery Officer*, NAVEDTRA 43443-C, Naval Education and Training Command, March 2012.

[3] CVN77 homepage. [Online]. Available: http://www.public.navy.mil/airfor/cvn77/PublishingImages/Photo_gallery/1006/100611-N-6509M-942.jpg

[4] John Wright media visit. [Online]. Available: http://johnwright.smugmug.com/Military/Navy/USS-Ronald-Reagan-Media-Visit/i-3LK4wXD/A

[5] S. E. Dreyfus and H. L. Dreyfus, "A five-stage model of the mental activities involved in directed skill acquisition," Tech. Rep., 1980.

[6] H. L. Dreyfuss and S. E. Dreyfuss, *Mind over Machine*. New York: Free Press, 1986.

[7] S. E. Dreyfus, "The five-stage model of adult skill acquisition," *Bulletin of Science, Technology & Society*, vol. 24, no. 3, pp. 177–181, 2004.

[8] F. Gobet and P. Chassy, "Expertise and intuition: A tale of three theories," *Minds and Machines*, vol. 19, no. 2, pp. 151–180, 2009.

[9] T. T. Baldwin and J. K. Ford, "Transfer of training: A review and directions for future research," *Personnel Psychology*, vol. 41, no. 1, pp. 63–105, 1988.

[10] J. W. Newstrom, "Leveraging management development through the management of transfer," *Journal of Management Development*, vol. 5, no. 5, pp. 33–45, 1986.

[11] A. L. Alexander, T. Brunyé, J. Sidman, and S. A. Weil, "From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games," in *The Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), NTSA, Orlando, Florida*, 2005.

[12] E. Shore and L. Sechrest, "Concept attainment as a function of number of positive instances presented." *Journal of Educational Psychology*, vol. 52, no. 6, p. 303, 1961.

[13] S. M. Cormier, "Transfer of training: An interpretive review," Tech. Rep., 1984.

[14] E. E. Smith, E. J. Shoben, and L. J. Rips, "Structure and process in semantic memory: A featural model for semantic decisions." *Psychological Review*, vol. 81, no. 3, p. 214, 1974.

[15] B. J. Underwood, “Attributes of memory.” *Psychological Review*, vol. 76, no. 6, p. 559, 1969.

[16] A. J. Flexser and E. Tulving, “Retrieval independence in recognition and recall.” *Psychological Review*, vol. 85, no. 3, p. 153, 1978.

[17] B. G. Witmer and M. J. Singer, “Measuring presence in virtual environments: A presence questionnaire,” *Presence: Teleoperators and virtual environments*, vol. 7, no. 3, pp. 225–240, 1998.

[18] M. Slater and A. Steed, “A virtual presence counter,” *Presence*, vol. 9, no. 5, pp. 413–434, 2000.

[19] L. Bacon and L. MacKinnon, “Using virtual and augmented reality to create realistic training events,” *Compass: Journal of Learning and Teaching*, vol. 3, no. 6, 2012.

[20] United States Government Accountability Office. GAO-12-725R Navy training. United States Government Accountability Office. [Online]. Available: http://www.gao.gov/assets/600/592056.pdf

[21] *Job Duty Task Analysis Management Manual*, NAVEDTRA 137, Naval Education and Training Command, July 2011.

[22] A. T. Corbett and J. R. Anderson, “Knowledge tracing: Modeling the acquisition of procedural knowledge,” *User Modeling and User-Adapted Interaction*, vol. 4, no. 4, pp. 253–278, 1994.

[23] M. R. Endsley *et al.*, *Theoretical Underpinnings of Situation Awareness: A Critical Review*. Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

[24] S. R. Ellis, “What are virtual environments?” *Computer Graphics and Applications, IEEE*, vol. 14, no. 1, pp. 17–22, 1994.

[25] R. T. Azuma *et al.*, “A survey of augmented reality,” *Presence*, vol. 6, no. 4, pp. 355–385, 1997.

[26] D. A. Bowman, C. Stinson, E. D. Ragan, S. Scerbo, T. Höllerer, C. Lee, R. P. McMahan, and R. Kopper, “Evaluating effectiveness in virtual environments with mr simulation,” in *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)*, vol. 2012, no. 1. NTSA, 2012.

[27] P. Milgram and F. Kishino, “A taxonomy of mixed reality visual displays,” *IEICE TRANSACTIONS on Information and Systems*, vol. 77, no. 12, pp. 1321–1329, 1994.

[28] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, "Recent advances in augmented reality," *Computer Graphics and Applications, IEEE*, vol. 21, no. 6, pp. 34–47, 2001.

[29] W. Carlson, "A critical history of computer graphics and animation," *The Ohio State University*. [Online]. Available: http://www.design.osu.edu/carlson/history/lesson17.html

[30] How virtual reality military applications work. [Online]. Available: http://www.science.howstuffworks.com/virtual-military.htm

[31] Codename: Blueshark. [Online]. Available: http://e2c2.ict.usc.edu

[32] Landing signal officer trainer. [Online]. Available: http://www.aerosimulation.com/programs/landing-signal-officer-trainer/

[33] Vr parachute trainer. [Online]. Available: http://www.navy.mil/view_image.asp?id=3523

[34] D. Lanman, H. Fuchs, M. Mine, I. McDowall, and M. Abrash, "Put on your 3d glasses now: the past, present, and future of virtual and augmented reality," in *ACM SIGGRAPH 2014 Courses*. ACM, 2014, p. 12.

[35] A. Maimone, D. Lanman, K. Rathinavel, K. Keller, D. Luebke, and H. Fuchs, "Pinlight displays: wide field of view augmented reality eyeglasses using defocused point light sources," in *ACM SIGGRAPH 2014 Emerging Technologies*. ACM, 2014, p. 20.

[36] K. Kiyokawa, Y. Kurata, and H. Ohno, "An optical see-through display for mutual occlusion of real and virtual environments," in *Augmented Reality, 2000.(ISAR 2000). Proceedings. IEEE and ACM International Symposium on*. IEEE, 2000, pp. 60–67.

[37] K. Hong, J. Yeom, C. Jang, J. Hong, and B. Lee, "Full-color lens-array holographic optical element for three-dimensional optical see-through augmented reality," *Optics letters*, vol. 39, no. 1, pp. 127–130, 2014.

[38] K. P. Keller, H. Fuchs *et al.*, "Simulation-based design and rapid prototyping of a parallax-free, orthoscopic video see-through head-mounted display," in *Proceedings of the 4th IEEE/ACM International Symposium on Mixed and Augmented Reality*. IEEE Computer Society, 2005, pp. 28–31.

[39] I. E. Sutherland, "A head-mounted three dimensional display," in *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, part I*. ACM, 1968, pp. 757–764.

[40] Magic leap. [Online]. Available: http://www.magicleap.com/#/home/

[41] Metaio press release 2013. [Online]. Available: http://www.metaio.com/press/press-release/2013/metaio-to-celebrate-10-years-of-augmented-reality-at-insidear-2013/

[42] M. Mine, D. Rose, B. Yang, J. van Baar, and A. Grundhofer, “Projection-based augmented reality in disney theme parks,” *Computer*, vol. 45, no. 7, pp. 32–40, 2012.

[43] Metaio. [Online]. Available: https://www.metaio.com/featured

[44] Epson moverio bt-200 demonstration of scope ar. [Online]. Available: http://newyorkinformer.us/?sk=video&vid=eVV5tUmky6c

[45] Digital life design 14 museum tour. [Online]. Available: http://www.youtube.com/watch?v=vHWmWAi9MFQ

[46] M. A. Livingston, L. J. Rosenblum, D. G. Brown, G. S. Schmidt, S. J. Julier, Y. Baillot, J. E. Swan II, Z. Ai, and P. Maassel, “Military applications of augmented reality,” in *Handbook of Augmented Reality*. Springer, 2011, pp. 671–706.

[47] D. C. Foyle, A. D. Andre, and B. L. Hooey, “Situation awareness in an augmented reality cockpit: Design, viewpoints and cognitive glue,” in *Proceedings of the 11th International Conference on Human Computer Interaction*, 2005, pp. 3–9.

[48] T. Oskiper, M. Sizintsev, V. Branzoi, S. Samarasekera, and R. Kumar, “Augmented reality binoculars,” in *Mixed and Augmented Reality (ISMAR), 2013 IEEE International Symposium on*. IEEE, 2013, pp. 219–228.

[49] C. R. Mayberry, S. Jaszlics, G. Stottlemyer, and G. Fritz, “Augmented reality training application for c-130 aircrew training system,” in *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)*, vol. 2012, no. 1. NTSA, 2012.

[50] C. Argenta, A. Murphy, J. Hinton, J. Cook, T. Sherrill, and S. Snarski, “Graphical user interface concepts for tactical augmented reality,” in *SPIE Defense, Security, and Sensing*. International Society for Optics and Photonics, 2010, pp. 76 880I–76 880I.

[51] D. Roberts, A. Menozzi, J. Cook, T. Sherrill, S. Snarski, P. Russler, B. Clipp, R. Karl, E. Wenger, M. Bennett *et al.*, “Testing and evaluation of a wearable augmented reality system for natural outdoor environments,” in *SPIE Defense, Security, and Sensing*. International Society for Optics and Photonics, 2013, pp. 87 350A–87 350A.

[52] D. Roberts, A. Menozzi, B. Clipp, P. Russler, J. Cook, R. Karl, E. Wenger, W. Church, J. Mauger, C. Volpe *et al.*, “Soldier-worn augmented reality system for tactical icon visualization,” in *Proceedings of the SPIE*, vol. 8383, 2012.

[53] C. Lee, S. Bonebrake, T. Höllerer, and D. A. Bowman, "A replication study testing the validity of ar simulation in vr for controlled experiments." in *ISMAR*, 2009, pp. 203–204.

[54] C. Lee, S. Bonebrake, D. A. Bowman, and T. Hollerer, "The role of latency in the validity of ar simulation," in *Virtual Reality Conference (VR), 2010 IEEE*. IEEE, 2010, pp. 11–18.

[55] C. Lee, S. Gauglitz, T. Hollerer, and D. A. Bowman, "Examining the equivalence of simulated and real ar on a visual following and identification task," in *Virtual Reality Short Papers and Posters (VRW), 2012 IEEE*. IEEE, 2012, pp. 77–78.

[56] C. Lee, G. A. Rincon, G. Meyer, T. Hollerer, and D. A. Bowman, "The effects of visual realism on search tasks in mixed reality simulation," *Visualization and Computer Graphics, IEEE Transactions on*, vol. 19, no. 4, pp. 547–556, 2013.

[57] Oculus rift. [Online]. Available: http://www.oculus.com/order/

[58] Zeiss vr one. [Online]. Available: http://zeissvrone.tumblr.com/

[59] Google cardboard. [Online]. Available: https://www.google.com/get/cardboard/

[60] *MOVERIO user guide*, BT-200, Epson, 2013.

THIS PAGE INTENTIONALLY LEFT BLANK

Initial Distribution List

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California